Practical Consideration of Climate Change

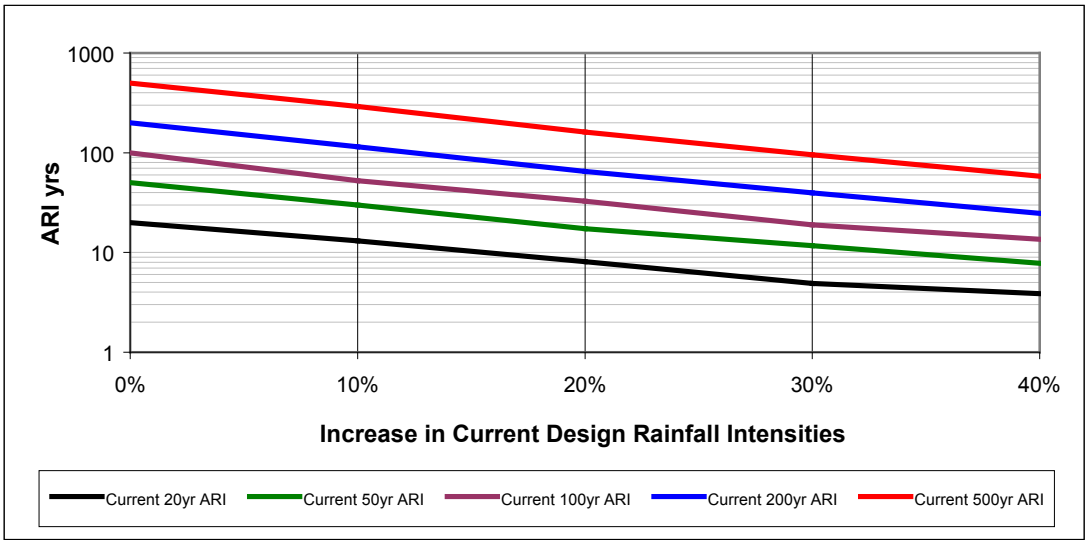
SUMMARY

Climate change is expected to have adverse impacts upon sea levels and rainfall intensities, both of which may have significant influence on flood behaviour at specific locations.

IPCC 2007 trends indicate that average global sea level rise (ignoring ice flow melt) may be between 0.18m to 0.59m by between 2090 and 2100. Add to this the ice flow melt uncertainty of up to 0.2m gives an adjusted global range of 0.18 to 0.79m. IPCC 2007 (0.1m) and recent CSIRO modelling (up to 0.12m) by McInnes et al indicate that mean sea level along the NSW coast is expected to rise by more than the global mean. Combining the relevant global and local information indicates that sea level rise on the NSW coast is expected to be in the range of 0.18 to 0.91m by between 2090 and 2100.

In addition, climate change impacts on flood producing rainfall events show a trend for larger scale storms (rainfall totals for the 40 year average recurrence interval (ARI) 1 day storm events) tend to increase by 2030 and 2070 as shown in **Table 1.** **Figure 1** shows the potential impacts of changes in current design ARIs due to increases in rainfall. CSIRO is currently undertaking further work in the area of shorter duration rainfall events which is expected to lead to further advice in this area in the future.

Figure 1 — Indicative Change in Design ARI as Rainfall Intensities Increase



Source: McLuckie et al, 2005

Climate Change Impacts and their Ramifications

The impacts of climate change and the associated ramifications upon the vulnerability of floodplain risk management (FRM) mitigation options and development decisions can be significant and therefore cannot be ignored in decision making today. The climate change factors affecting flood behaviour and their degree of influence vary with location and therefore it is essential that studies for specific locations consider these impacts and their ramifications. McLuckie et al provides examples of the ramifications of potential impacts including:

- Sea level rise. For example, annual average damage (AAD) to a house built at the flood planning level (FPL) in an area where flood levels are directly controlled by ocean levels could increase by more than 1000% due to a high sea level rise scenario by 2090 to 2100.
- Increased frequencies of events due to increased rainfall intensities (**Figure 1**). For example, in a particular town not influenced by sea level rise, a 30% increase in rainfall could increase AAD by 300%.

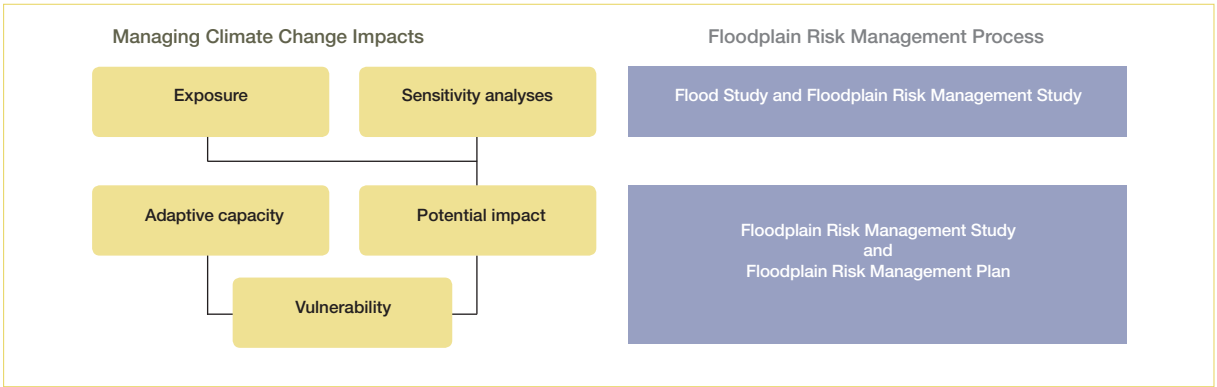
Therefore the 2005 Floodplain Development Manual (the Manual) requires flood studies and FRM studies to consider and where necessary manage climate change implications and associated vulnerabilities as part of strategic management of flood risk **(Figure 2)**. Adaptation may involve consideration of more robust management options now or management options that enable effective adaptation to climate change in the future, i.e. adaptive capacity built into management options.

Table 1 — Indicative Change in Extreme Rainfall 1 day Totals and Evaporation for 2030 & 2070

Source: CSIRO, reports prepared for the NSW Government, 2007. Climate Change in NSW Catchments Series

Catchment	Extreme Rainfall (40 Year 1 day rainfall total) Projected Change 2030	Extreme Rainfall (40 Year 1 day rainfall total) Projected Change 2070	Evaporation Projected Change 2030	Evaporation Projected Change 2070
Border Rivers-Gwydir	+3% to +7%	+10% to +15%	+2% to +13%	+4% to +40%
Central West	-3% to +20%	-3% to +15%	+2% to +13%	+4% to +40%
Hawkesbury-Nepean	-3% to +12%	-7% to +10%	+1% to +8%	+2% to +24%
Hunter-Central Rivers	-10% to +12%	-7% to +10%	+1% to +13%	+2% to +40%
Lachlan	-3% to +25%	-7% to +29%	+2% to +13%	+4% to +40%
Lower Murray-Darling	+0% to +25%	+0% to +29%	+2% to +13%	+4% to +40%
Murray	-3% to +25%	-7% to +29%	+2% to +13%	+4% to +40%
Murrumbidgee	+7%	+5%	+1% to +13%	+2% to +40%
Namoi	+3%	+10%	+2% to +13%	+4% to +40%
Northern Rivers	-10% to +5%	+5% to +10%	+1% to +13%	+4% to +40%
Southern Rivers	+7%	+5%	+1% to +13%	+2% to +40%
Sydney Metropolitan Catchments	-3% to +12%	-7% to +10%	+1% to +8%	+2% to +24%
Western Catchment	-10% to +34%	-7% to +16%	+1% to +13%	+4% to +40%
Maxima	-10% to +34%	-7% to +29%	+1% to +13%	+2% to +40%
Average	-2% to +15%	-1% to +15%	+1% to +12%	+3% to +38%

Figure 2 - Managing Climate Change Impacts (adapted from Allen Consulting Group 2005)



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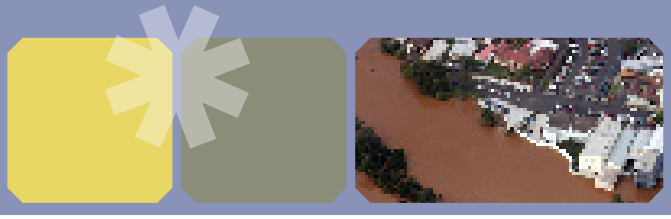

This guideline provides the following advice to assist in considering climate change in managing flood risk:

Section 1. Assessing climate change impacts through modelling sensitivity analyses.

Section 2. Determining whether climate change is a key issue at a particular location. This depends upon the impacts on flood damages and increased frequency of exposure of people to flood hazard.

Section 3. Incorporating climate change in floodplain risk management plan development considerations, and in new and current works projects and planning strategies.

Section 4. Outlining some potential climate change management strategies for existing and future development and associated practical issues.

Recommendation

It is recommended that this guideline be used as the basis for examining climate change in projects undertaken under the State Floodplain Management Program and the 2005 Floodplain Development Manual.

All associated reports are to have a section that specifically addresses climate change. The scope of reporting should reflect the scope of the particular study and as a minimum include an outline of the modelling and analyses undertaken and their limitations, discuss the impacts of climate change on flood behaviour and outline any associated conclusions and recommendations. Where the study also looks at ramifications of flooding and examine management options these issues should also be addressed in the climate change section of the report.

References

McLuckie D, Lord D, Gibbs J. "Climate Change — The Future is Uncertain. Practical Consideration of Climate Change in Flood Risk Management in NSW". 46th Annual NSW FMA Conference, Lismore, March 2006.

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Abbs D., Aryal S., Campbell E., McGregor J., Nguyen K., Palmer M., Rafter T., Watterson I., Bates B., October 2005. "Projections of Extreme Rainfall and Cyclones." Draft Final Report to the Australian Greenhouse Office.

CSIRO, prepared for the NSW Government, 2007. Climate Change in NSW Catchments Series. Individual reports cover the following areas of NSW: Border Rivers-Gwydir, Central West, Hawkesbury-Nepean, Hunter-Central Rivers, Lachlan, Lower Murray-Darling, Murray, Murrumbidgee, Namoi, Northern Rivers, Southern Rivers, Sydney Metropolitan, Western.

CSIRO and Bureau of Meteorology, Climate Change in Australia, Observed Changes and Projections. October 2007.

CSIRO and Bureau of Meteorology, Climate Change in Australia, Technical Report 2007. Released October 2007. Various authors.

Section 1 Sensitivity Analysis — Timeframe and Scenario Selection

The Summary and **Figure 1** outline the potential climate change impacts on sea levels and on flood producing rain.

Whatever climate change scenario is adopted may be exceeded in the future as climate change continues. Therefore the precautionary principle suggests consideration of the full range of scenarios.

The 2090-2100 (ocean) and 2070 (rainfall) timeframes have been selected as the basis for current decisions for development and management options unless it can be shown to the satisfaction of the relevant Council or DECC that the associated decisions or options will not be relevant by this timeframe. Longer timeframes could also be considered, particularly for critical infrastructure.

The following sensitivity analyses are recommended:

- for sea level where relevant to the study area:
  - 0.18m (Low Level Ocean Impacts
  - 0.55m (Mid Range Ocean Impacts
  - 0.91m (High Level Ocean Impacts

In addition until more work is completed in relation to the climate change impacts on rainfall intensities the following sensitivity analyses are recommended:

- Rainfall Intensities. Increases of:
  - 10% in peak rainfall and storm volume
  - 20% in peak rainfall and storm volume
  - 30% in peak rainfall and storm volume

Note that the combination of ocean event ARI with flood event ARI should be discussed with DECC floodplain risk management (FRM) staff due to joint probability issues. Sensitivity analyses should also consider combined sea level rise and rainfall factors where applicable.

Climate change related sensitivity analyses should be in addition to the usual sensitivity analyses involved in flood and FRM studies undertaken in accordance with the Manual.

Section 2 Is Climate Change a Significant Issue for the Location?

The potential impacts of climate change and the associated ramifications will vary significantly with location. Therefore the Manual highlights the need for climate change to be considered in both the flood study and the FRM study to assess the location specific impacts and ramifications and consider associated adaptive FRM strategies.

Any management measures relating to a specific ARI flood event are more susceptible to climate change than those relating to an extreme or probable maximum flood (PMF) event as the associated emergency response management decisions are inherently more robust.

Whilst climate change impacts and ramifications may vary within and between study areas, the following questions will assist in assessing the sensitivity of the study area or specific portions of it to the impacts of climate change.

1. Will climate change result in new floodways developing in the key design events? If so are the associated ramifications to existing or proposed future development or management options significant?
2. Will climate change have significant implications for flood hazard in the study area? If so can this be managed through changes to existing measures or by using new mitigation measures or development controls?
3. Will climate change result in a significant increase in the frequency of inundation? If so is this acceptable, ie is the land still viable or does this increased frequency need to be mitigated? **Figure 3** indicates that the current 100 year ARI design ocean level may occur monthly with the high climate change sea level rise scenario by 2090 to 2100. The frequency of this occurrence and its chance of coinciding with flood producing rainfall events will therefore increase significantly.
4. Will climate change result in a significant increase in frequency of exposure to hazard? If so can this be managed?
5. Will climate change significantly impact upon flood damages? If so, can the community cope with the increased damage or is it necessary to mitigate impacts to reduce the ramifications? Do conditions for new development need to change to reduce the potential growth in damages?

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6. Is the effectiveness of existing or proposed management options vulnerable to climate change? If so are they still appropriate? Do new options need to be considered? Can existing or proposed management options be altered to build in adaptive capacity now or in the future? Section 4 provides some advice on building in adaptive capacity.

7. Are existing or proposed development options or controls vulnerable to climate change? If so are they still appropriate with climate change? If not, can they be altered to allow for climate change? Is the opportunity cost of the alteration significant for the location? Do we need to allow for structural measures to protect new areas in the event of significant levels of climate change? Section 4 provides some advice on building in adaptive capacity.

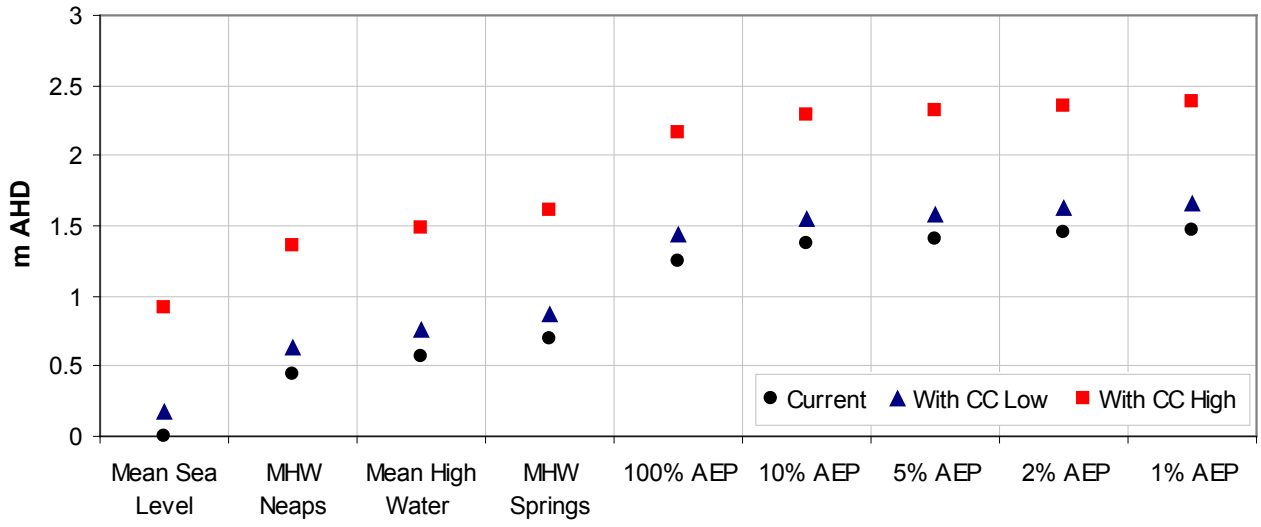
Section 3 Considerations of Climate Change in FRM Projects

The Manual highlights the need for climate change to be considered in both the flood and FRM study to determine the potential impacts on flood behaviour and to enable robust and informed decisions on appropriate adaptive strategies for managing flood risk into the future. These strategies need to be documented in the FRM Plan.

Where the project or decision making has progressed beyond this stage and climate change has not been considered, it is recommended that it now be considered to ensure that decisions and options are robust and adaptive enough to deal with relevant climate change impacts for the locality. This may be undertaken as part of a review to the FRM plan (required at least every 5 years, under Section 2.7 of the Manual), as part of the preliminary concept design for a works project or as part of a review of works or development strategies that have been implemented.

Table 2 provides an indicative scope of works to ensure that relevant climate change impacts for the locality are adequately understood and considered in informed decision making. The documentation of decisions in the FRM Plan and their incorporation into associated implementation strategies must also be ensured.

Figure 3 - Differences in Key Ocean Levels — 2090-2100 (IPCC 2007 + CSIRO McInnes et al)



Source: Mcluckie et al (2005)

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Table 2 - Consideration of Climate Change in FRM Projects

Number and Description of Issue		Flood Study	FRM Study & Plan	FRM Plan Review	Review of New Works Projects & new Planning Strategies	Review of Completed Mitigation Works & Current Planning Strategies
1	Incorporate climate change sensitivity analyses into modelling of current & fully developed catchment model behaviour, flood damage assessments and management option modelling & assessment. Synopsis in main report with detail in appendices.	Yes	Only if not dealt with in Flood Study	Only if not dealt with earlier	Only if not dealt with earlier	Only if not dealt with earlier
2	Assess and report on the potential impacts of climate change on flood behaviour and associated ramifications for flood damages, exposure of people to flood hazard and regularity of inundation. Summarise in main report with more detail provided in appendices.	n/a	Yes	Only if not dealt with earlier	Only if not dealt with earlier	Only if not dealt with earlier
3	Examine and report on the appropriateness of current or proposed management strategies for existing and future development to deal with long term climate change impacts (ie is the type of option robust enough to deal with climate change implications). Consideration needs to be given to whether climate change impacts will mean that current management strategies are not viable.	n/a	Yes	Only if not dealt with earlier	Only if not dealt with earlier	Only if not dealt with earlier
4	For viable options, examine the vulnerability of current or proposed management options to climate change. Consider items in Section 4.	n/a	Yes	Only if not dealt with earlier	Only if not dealt with earlier	Only if not dealt with earlier
5	For viable options, examine the vulnerability of current or proposed development strategies and associated conditions to climate change. Consider items in Section 4.	n/a	Yes	Only if not dealt with earlier	Only if not dealt with earlier	Only if not dealt with earlier
6	Examine the practicality of building adaptive capacity into management options either now or in the future. Need to consider viability and how issues raised in Section 4 can be addressed.	n/a	Yes	Only if not dealt with earlier	Only if not dealt with earlier	Only if not dealt with earlier
7	Examine the practicality of building adaptive capacity into development strategies/conditions either now or in the future. Need to consider viability and how issues raised in Section 4 can be addressed.	n/a	Yes	Only if not dealt with earlier	Only if not dealt with earlier	Only if not dealt with earlier
8	Make informed decisions on managing vulnerability to climate change through either building adaptive capacity into management options and development strategies and controls or accepting the additional risk after considering the associated ramifications.	n/a	Yes	Yes	Yes	Yes
9	Incorporate synopsis of climate change impacts, ramifications and associated decisions, including any associated implementation timetable, into the FRM Plan.	n/a	Yes	Yes	Yes	Yes

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Section 4 Managing Vulnerability of Options and Decisions

The vulnerability of mitigation options or development decisions to climate change varies with a range of factors including the:

- Specifics of the location including the degree of exposure to flooding, what controls the flooding (flow, volume, particular structures) and whether flooding is influenced by sea level.
- Type of management option or development decision being considered and whether it relates to a specific ARI or an extreme event. Options for managing extreme events generally relate to emergency response management which, by their nature,need to be robust.
- Source of climate change vulnerability. This can come from either (or both) sea level rise and increase in rainfall intensity depending upon the location and the particular "controls" influencing flooding.
- Change in the frequency of inundation. **Figure 3** shows that with the high climate change sea level rise scenario high ocean levels regularly occur, ie. the current 100 year ARI static design ocean level occurs almost monthly by 2090-2100. This raises issues for land habitability and local drainage systems.

The impacts on flood behaviour, regularity of flooding, and damage/danger from flooding are very location specific and need to be assessed on this basis. This requires location specific strategies to manage climate change considering the vulnerability of the location, the type of management options or development decisions being made and the benefits of these strategies for the specific location.

The climate change management strategies put forward below are not exhaustive. They concentrate on the more vulnerable ARI related management options and development decisions. They are based upon managing the ramification of particular climate change scenarios and therefore aim to ensure a security to decisions for the adopted planning horizons. No matter which climate change scenario is adopted, management strategies for specific ARI events may be overwhelmed at some point as change continues.

In areas where sea level rise doesn't influence flood behaviour, climate change vulnerability comes from increased rainfall intensities and storm frequency. Where the variation of flood levels with ARI is low, the impacts and associated ramifications are unlikely to be significant. However, where the variation in flood level with ARI is high and climate change ramifications to people or property are significant careful consideration needs to be given to strategies for managing the impact.

In areas with potential climate change impacts from sea level rise, climate change impacts may also be influenced by increased rainfall intensities and storm frequency depending upon the controls influencing flood behaviour.

Section 4.1 Management Strategies Where Climate Change Ramifications are Considered MINOR

For Future Development

The following climate change management strategies are among those that could be considered:

- Adopt a current 100yr ARI flood level as the basis for flood planning levels (FPLs) and fill levels and accept that flood risk will increase over time. The potential long term protection level and associated increase in potential damages should be recognised and documented and the community informed.
- Use higher FPLs by adopting a climate change factor specific fof the location in addition to general freeboard. This will provide 100yr ARI protection at a given point in the future with a slightly higher level of protection at present.

For Existing Development

The following options are among those that should be considered:

- Do nothing, where no works are proposed to protect existing development. This decision is unlikely to change if climate change ramifications are minor.
- If works are proposed to protect existing development, consider the feasibility of allowing for climate change impacts in these projects. This may involve considering the practicality and cost versus benefit of allowing for changes now or as a modification in the future. The decision could be to do nothing, or to do nothing now but allow to upgrade in a practical way in future, or to allow for impacts in the project now.

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Section 4.2 Management Strategies For Future Development Where Climate Change Ramifications Are Considered SIGNIFICANT

Figures Future 1 to 7 provide examples of strategies that could be considered to manage climate change to future development where impacts are significant. These examples consider the variation in ramifications dependant upon location and the potential to effectively and practically manage these impacts. A general discussion of possible strategies with reference to relevant figures follows.

- Where the land being assessed for development may be considered marginal from a flood risk and coastal inundation perspective. With high climate change impacts the flood risk and coastal inundation impacts will become more critical. The land may not be viable for standard residential or other development.

  Therefore it may be appropriate to consider an alternate location for the development. The site could be used for purposes more compatible with the long term risk. Examples of relevant uses may include parklands, playing fields, golf courses, other recreational pursuits or agriculture or environmental purposes. **Future 1.**

  Alternatively consideration could be given to use of the site for development types that allow for planned retreat from the affected land within a specific timeframe or once climate change impacts on sea level rise or flood risk meet specific stipulated criteria. In these cases the criteria for retreat or withdrawal from the land and methods for their measurement need to be set and agreed upon prior to any approval for development.

  Depending upon the current risk and potential climate change impacts for the specific site and development alternatives, compatible uses to consider could include such developments as:

  — tourist or short term caravan parks (with no permanents occupants or mobile homes) and low cost permanent facilities where investment decisions can be made based upon known conditions of abandonment and removal; or

  — supporting land/facilities for cluster housing for residential or tourist development. Significant buildings located on adjacent higher land where risks can be effectively managed; or

  — tourist or commercial development where investment decisions are based upon known conditions of abandonment and removal.

- Include a climate change factor determined for the location in FPLs and fill levels on top of general freeboard to provide the desired protection at a given point in the future but higher protection at present. **Future 2.**
- Adopt the current 100yr flood as the basis for FPLs and fill levels and accept that flood risk will increase over time. The long term protection level (ARI) and increase in potential damages should be assessed. As potential climate change ramifications for future development may be significant this may be unacceptable to the community. **Future 3.**
- Investigate alternative options considering both present and future risk exposure. These may allow for practical development of properties but enable climate change impacts and ramifications to be managed over the long term. This could involve:

  — having a compromise position on FPLs and fill levels between the options outlined previously. Examples include: allowing for low change scenarios in fill levels but high change scenarios in floor levels, **Future 4;** making no allowance for change in fill levels but allowing for high change scenarios for floor levels, **Future 5.**

  — FPLs at current minimum levels but with a requirement for two-storey housing with flood compatible structural materials on the bottom storey. This reduces damage potential and exposure of contents to flooding even in the long term. However, this may not address issues with frequent inundation, particularly in areas where sea level controls flooding.

  — In special developments, eg schools, adopt FPLs and fill levels based upon existing situations but include elements to reduce exposure. For instance placing more vulnerable development in less exposed position on site or perhaps on a second storey, and consider improving the structural compatibility of buildings to flooding.

  — Considering the potential to retrofit solutions when significant climate change impacts occur that were not allowed for. Is it possible to set land aside now to enable the future construction of a levee to manage climate change impacts? This involves examining cost effective options that could be effectively and practically implemented in the future. Examples include: not allowing for climate change scenarios in

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fill levels but allowing for high climate change scenarios in floor levels with control on frequency of inundation by a levee built now or in the future, **Future 6;** making no allowance for climate change in fill or floor level conditions but allowing for the construction of a levee to reduce flood risks for the high climate change scenario, **Future 7.**

Any potential climate change impacts on emergency response management also needs consideration in developing a management strategy.

Development options should be considered on the basis that:

- Development of the area is considered appropriate (flow conveyance maintained, cumulative impacts of development managed, and residual hazard is manageable through development controls and/or emergency response management in accordance with the strategic requirements of the Manual.
- Flood related development conditions are put in place regardless of climate change.
- Emergency response management can be managed for the existing conditions.
- The following issues are considered in deciding upon an appropriate climate change management strategy:
  1. Does climate change impact upon the areas practical for development? What is the opportunity cost of reducing development potential due to climate change? Is other more practical or less exposed land available?
  2. Does the option provide the community with the degree of protection it believes it should receive?
  3. Does flood hazard in the planning flood alter with climate change? Is the additional hazard to people resulting from increased flood depths or velocities in the same ARI events significant? Can it be successfully and practically managed?
  4. Does flood hazard for events greater than the planning flood up to the PMF alter with climate change? Is the additional hazard to people resulting from increased flood depths or velocities in the same ARI events significant? Can it be successfully and practically managed?
  5. Does frequency of exposure of people to hazardous flood situations external to buildings alter with climate change? How does this compare to strategy Future 2 and what are the associated extra emergency response management issues? Can the additional hazard and issues be effectively managed?
  6. Does regularity of inundation of land alter with climate change? What are the ramifications for habitability of the land particularly where sea level rise influences climate change? Can this be effectively managed?
  7. What extra flood damage is the community exposed to due to climate change? Is this acceptable or manageable?
  8. What is the extra cost involved in allowing for the future impacts? For example, are there extra development costs for fill and setting aside land for levees, extra building costs, or extra costs for levee construction and maintenance in the future? Are there more practical sites with less exposure available?
  9. What additional emergency response management issues relate to evacuation due to increased frequency of inundation? How can these be managed?
  10. Can the area behind a climate change management levee be effectively drained, given the potential water levels outside the levee? Is pumping infrastructure required? What are the additional costs of drainage?
  11. What are the practical, aesthetic and environmental issues? How can the potential resistance of residents to loss of amenity of property (water views or access) in the future due to the construction of a levee or due to house raising be dealt with?
  12. Can climate change impacts be effectively managed by a future strategy?
  13. What is the potential to adapt with changed climate change information? Is this feasible?
  14. If these issues cannot be addressed is this still the right option? Is there an alternative location for development? Are other options feasible?
  15. Are planned retreat options viable? Would these be compatible with current levels of risk? Is it possible to effectively condition and therefore control retreat? What forms of land use would be appropriate prior to retreat? Can infrastructure investment be controlled given the relatively short term of possible occupation?

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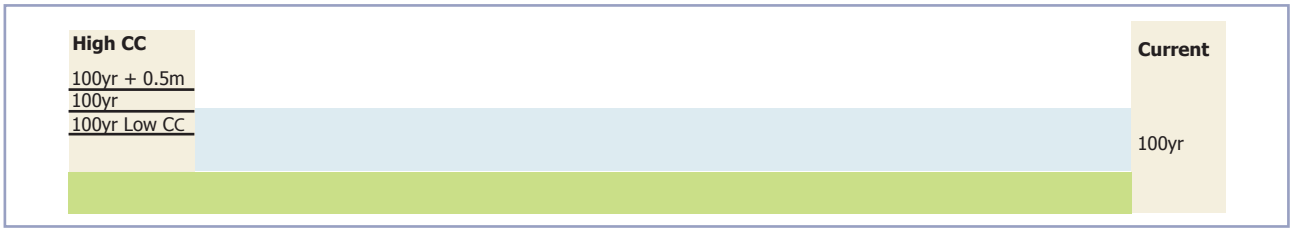
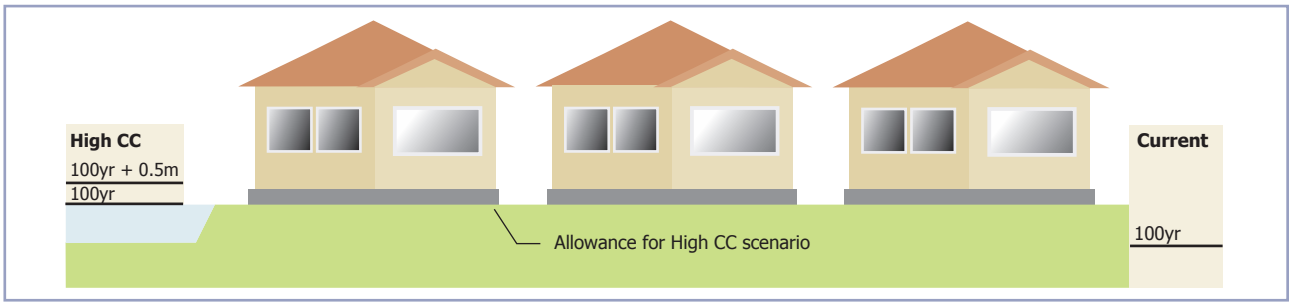
Strategy Future 1 — Site not Occupied Long Term

Develop in an alternate location where flood risk with climate change is more acceptable to the community or develop in an alternative way compatible with long term risk (parklands, play grounds or as a supporting area for cluster development on higher land) or consider development options that allow for planned retreat.



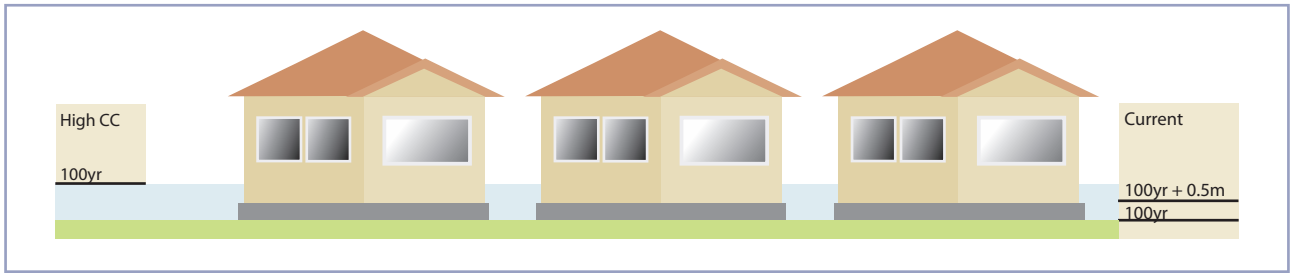
Strategy Future 2 — Allow for High Scenario Climate Change Scenario Now

Minimum fill and floor levels include an allowance for high scenario climate change now. This allows for changes in rainfall intensities and sea level rise.



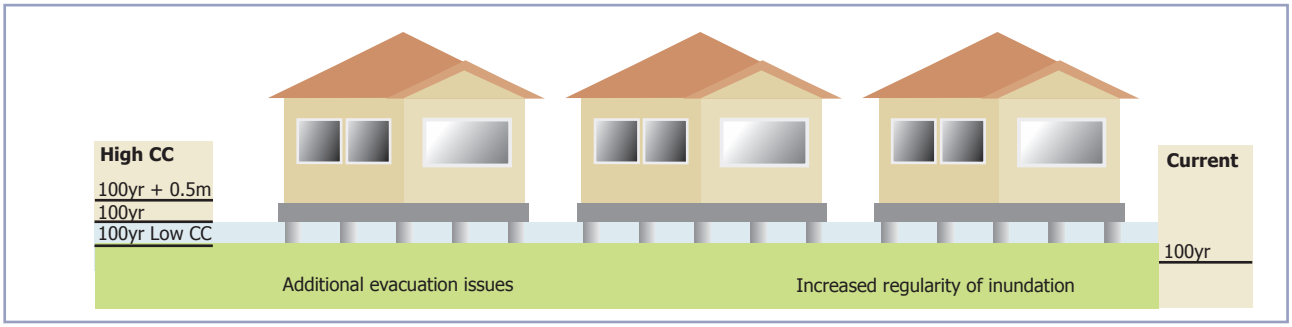
Strategy Future 3 — Development Conditions have No Climate Change Allowance

Minimum fill and floor levels based upon existing situation and additional flood risk due to climate change accepted.



Strategy Future 4 —High Level Climate Change Allowed for in Floor Levels. Low Climate Change in Fill Levels

Provides additional protection for homes with surrounding land inundated more regularly in the long term.



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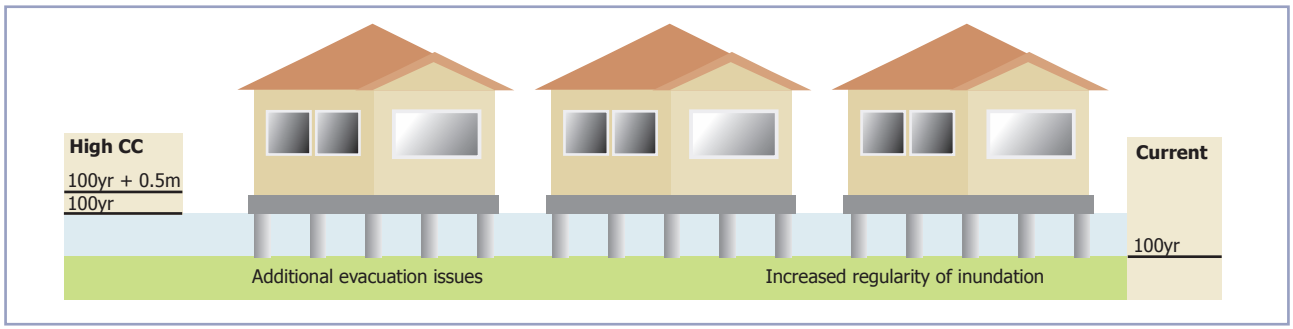
Version No: 1.0 Status: Final Issue date 25/10/2007 Authorisation: Director Coast & Floodplain Management

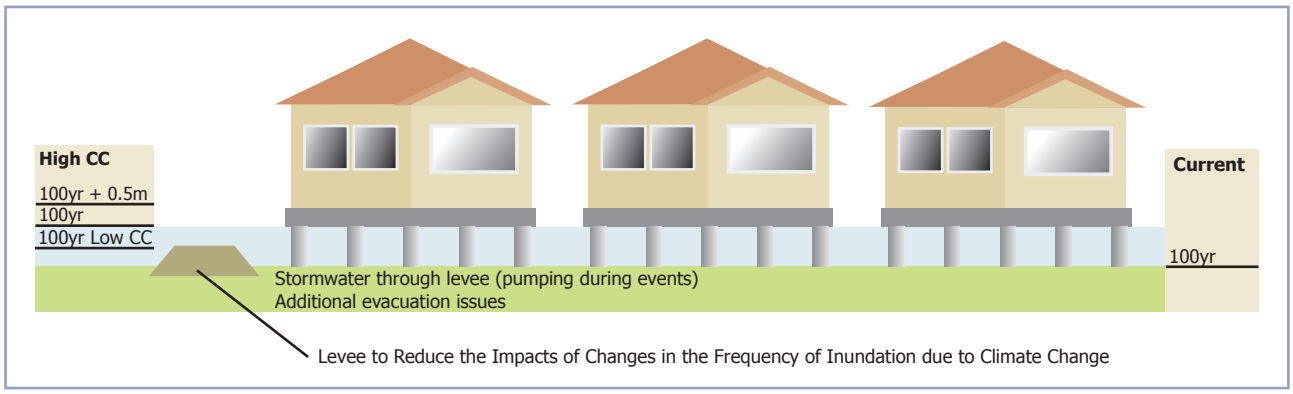
Strategy Future 5 — Fill to Current 100 year Flood Level. Floor Levels to High Climate Change Scenario

Provides protection to homes but will have increased frequency of inundation and therefore more emergency response issues. Depending upon frequency of inundation land may not be habitable in the long term.



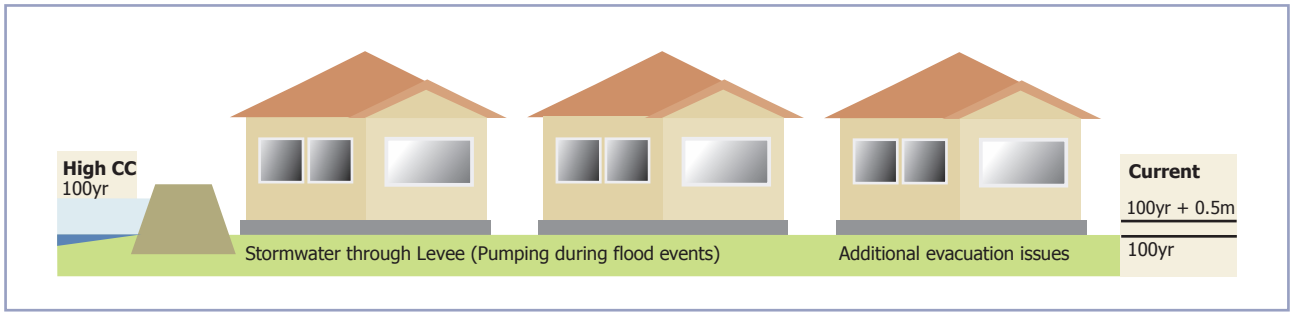
Strategy Future 6 — Minimum Fill Levels for Current 100 year. Floor Levels to High Climate Change. Levee to Reduce Frequecy of Inundation

Minimum Fill Levels for Current 100 year. Floor levels consider high climate change scenario. Levee built now or in the future to reduce frequency of inundation, possibly to low climate change scenario



Strategy Future 7 — Development Controls to Current Conditions. Levee Built to Manage Climate Change Impacts

Minimum fill and floor levels for current conditions. Levee built now or in the future to provide protection for climate change.



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Section 4.3 Management Strategies For Existing Development Where Climate Change Ramifications Are Considered SIGNIFICANT

Figures Existing 1 to 6 provide examples of strategies that could be considered to manage climate change to existing development where the impacts are significant. These examples consider the variation in climate change ramifications dependant upon location and the potential to effectively and practically manage these impacts.

- Where no works are proposed to protect existing development, **do nothing**. The FRM study needs to consider whether climate change ramifications justify the need for works and if so the potential options for works in the long term, and their practicality and feasibility. This may enable land to be set aside now to address this issue as necessary in the future.
- If works are proposed to protect existing development consider the feasibility of **including a climate change allowance as part of the works**. This involves considering the practicality and cost versus benefit of allowing for changes either now or as a modification in the future. A decision could then be made to do nothing, do nothing now but allow for the potential to practically upgrade the works in the future, or to upgrade the protection as part of the current project.

Some other possible climate change management strategies for existing development are outlined below: These need to consider:

- Whether existing management measures are in place or being developed to manage existing flood risk.
- Whether emergency response management planning considers the existing flood hazards in the areas.
- The following issues in deciding upon whether a strategy for managing climate change to existing development is appropriate:
  1. Does the option provide the community with the degree of protection it believes it should receive?
  2. Does the flood hazard in the planning flood alter with climate change? Is the additional hazard to people resulting from increased flood depths or velocities in the same ARI events significant? Can it be successfully and practically managed?
  3. Does the flood hazard in events greater than the planning flood up to PMF alter with climate change? Is the additional hazard to people resulting from increased flood depths or velocities in the same ARI events significant? Can it be successfully and practically managed?
  4. Does frequency of exposure of people to hazardous flood situations external to buildings alter with climate change? What are the associated extra emergency response management issues? Can the additional hazard and issues be effectively managed?
  5. Does regularity of inundation of land alter with climate change? What are the ramifications for habitability of the land particularly where sea level rise influences climate change? Can this be effectively managed?
  6. What extra flood damage is the community exposed to due to climate change? Is this acceptable or manageable?
  7. What is the extra cost involved in allowing for the future impacts?
  8. What additional emergency response management issues relate to evacuation once the levee overtops or due to increased frequency of inundation? How can these be managed?
  9. Can the area behind the levee be effectively drained given the potential water levels outside the levee with climate change? Is pumping infrastructure required? What are the additional costs of managing drainage?
  10. What are the practical, aesthetic and environmental issues and how can the potential resistance of existing residents to loss of amenity of property (water views or access) due to construction of the levee or due to house raising be dealt with?
  11. Can climate change impacts be effectively managed by a future strategy?
  12. What is the potential to adapt with changed climate change Information?
  13. If these issues cannot be addressed is this still the right option? Is there an alternative feasible option?

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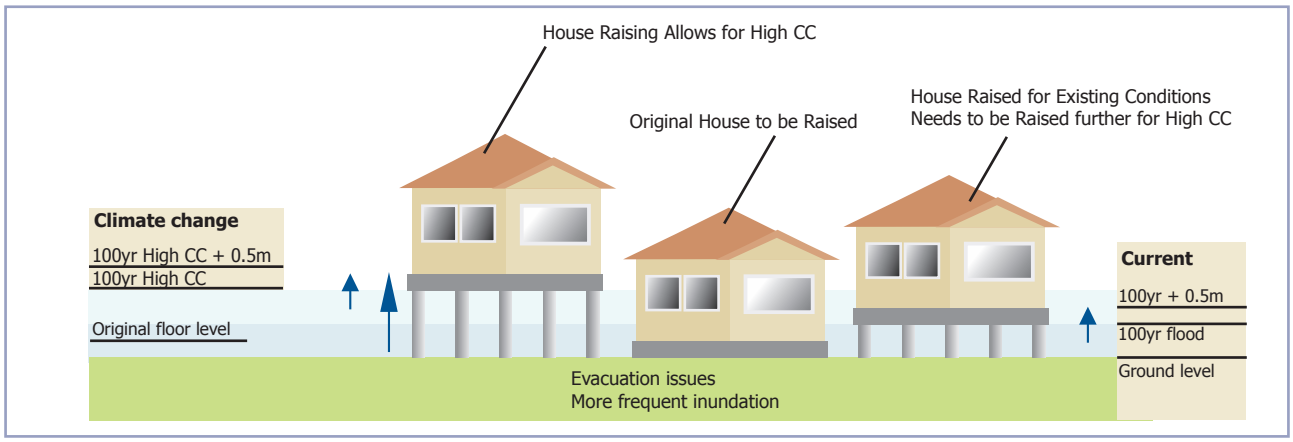
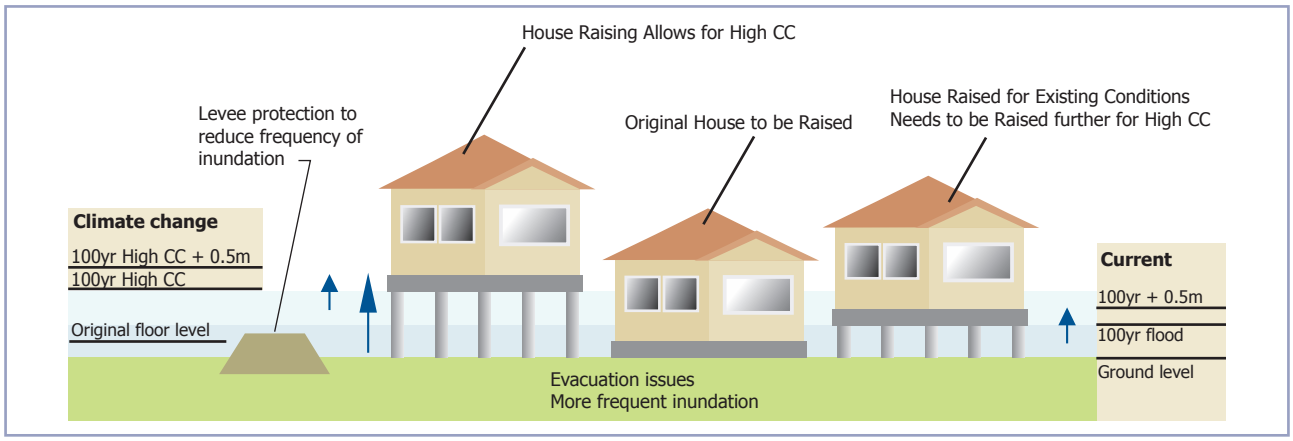
Strategy Existing 1 - New or Existing Voluntary House Raising (VHR) and Voluntary Purchase (VP). Extend Scheme to Allow for High Scenario Climate Change

VP properties are in most hazardous conditions. VHR reduces damage. No control of frequency of inundation and therefore depending upon the current ground level and climate change impacts land may become uninhabitable.



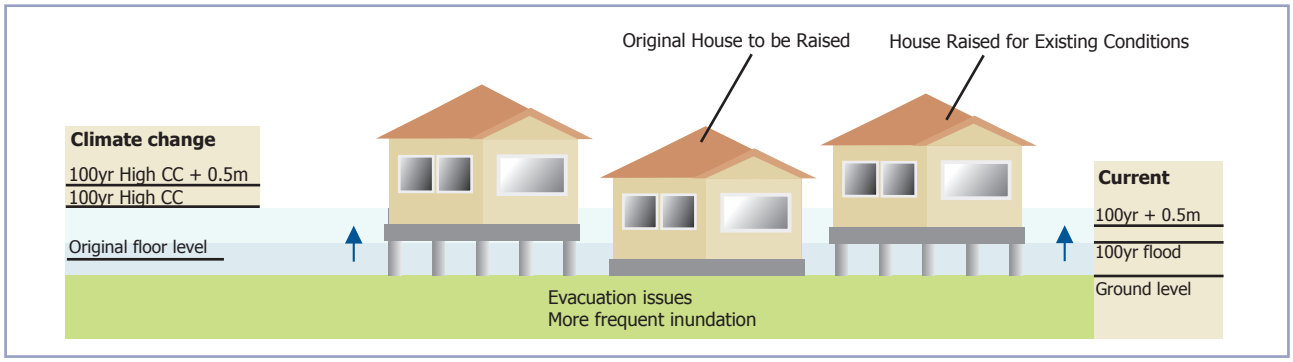
Strategy Existing 2 - New or Existing VHR and VP. Extend Scheme to Allow for High Scenario Climate Change. Include a Levee to Reduce Inundation Frequency.

VP properties are in most hazardous conditions. VHR reduces damage. Frequency of flooding reduced by a levee to enable land to remain habitable..



Strategy Existing 3 - New or Existing VHR and VP. Allow for Existing Situation and Accept Climate Change Impacts

VP properties are in the most hazardous conditions. VHR reduces damage for existing conditions. Additional damage due to climate change accepted. No control of frequency of inundation and therefore depending upon the current ground level and climate change impacts land may become uninhabitable.



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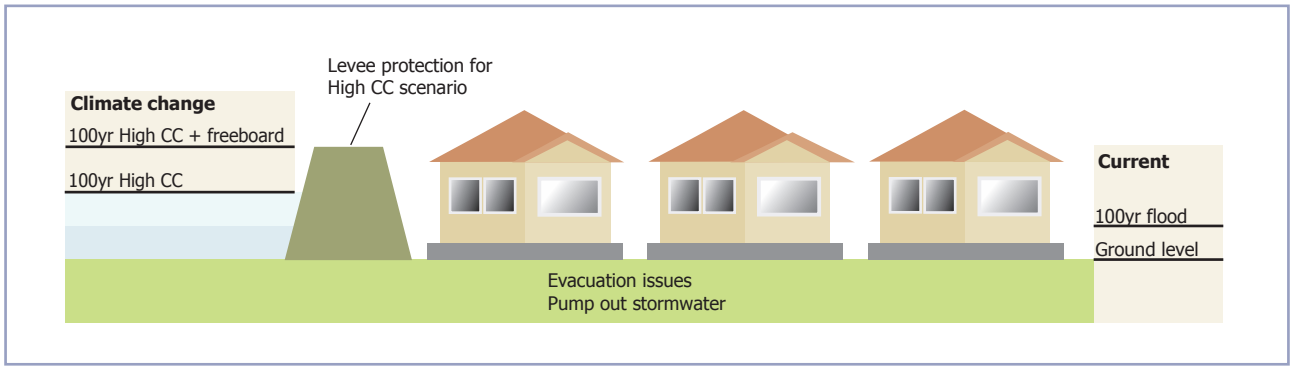
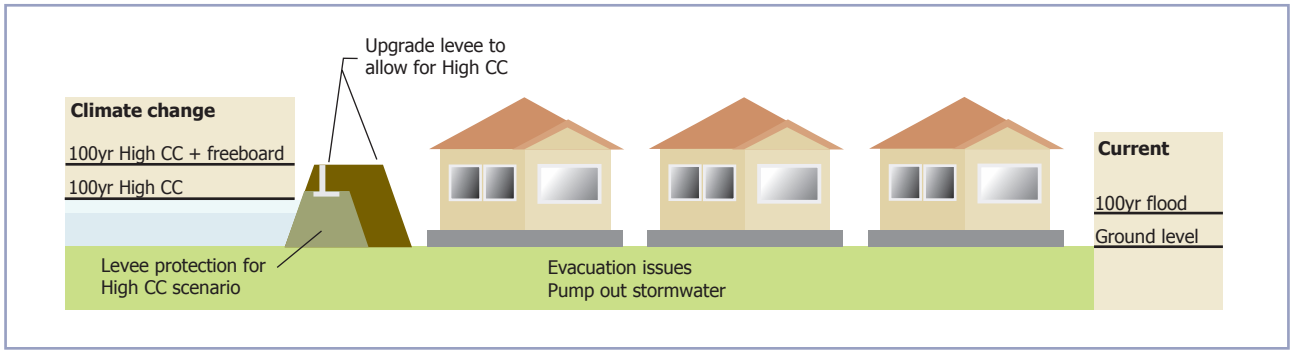
Strategy Existing 4 – Build New Levee or Upgrade Levee Now to Allow for High Climate Change scenario

Levee provides protection to property for high climate change impacts and existing flood risks.



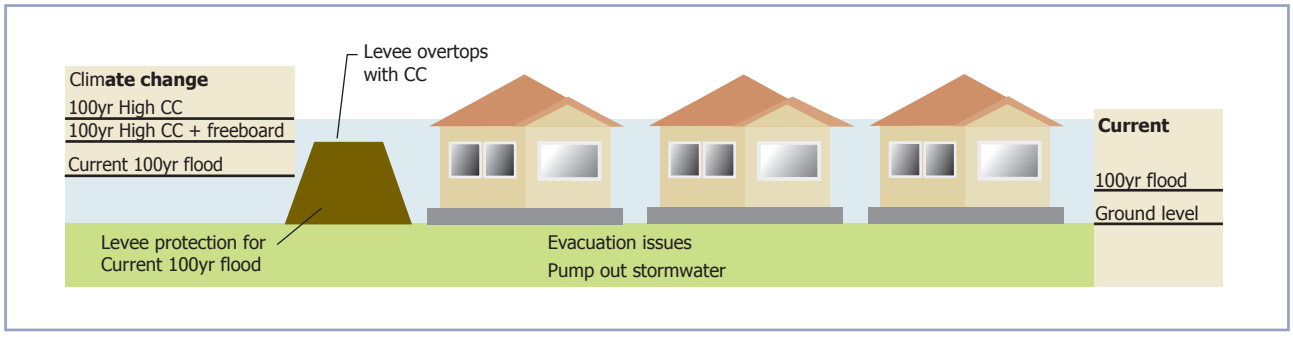
Strategy Existing 5 – Build New Levee for Existing Flood Situation but Design to Enable Upgrading for Climate Change or Examine the Ability to Upgrade an Existing Levee for Climate Change

Levee provides protection to property for high climate change impacts and existing flood risks once upgraded.



Strategy Existing 6 – Build New Levee for Existing Flood Situation Without Climate Change Allowance

Levee provides protection to property for existing flood risk but protection reduces overtime due to climate change impacts.



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TITLE: [EO-OC] Climate Change Impacts on Flooding

ORIGIN:

Planning & Infrastructure

SUMMARY OF REPORT:

The potential impacts of climate change on sea levels and rainfall intensities have implications for floodplain management and related land use planning. The Department of Environment and Climate Change (DECC) have recently released a Guideline that recommends a range of climate changes scenarios be considered in flood studies. Further, a recent Land and Environment Court decision sets a precedent whereby potential changes in flood behaviour due to climate change must be properly considered in determining development applications.

It is proposed to model the impacts of climate change in a revision of the Tweed Valley Flood Study 2005 and the yet to be completed Coastal Creeks Flood Study.

Consideration of climate change impacts on floodplain planning and management of the Tweed Valley could commence in late 2008. As the Coastal Creeks Flood Study will not be completed until late 2008 it will be well into 2009 before the subsequent Coastal Creeks Floodplain Risk Management Study is commenced, making consideration of climate change impacts on floodplain planning and management of the coastal creeks area some years away.

Council has a number of locality and strategic planning studies currently underway. The NSW Department of Planning is also currently revising the land use and population densities proposed in the Tweed Heads Masterplan for both Tweed Heads and Tweed Heads South. Due to the above timetables, it is unlikely these studies will have the benefit of being informed by the climate change based modelling on flood behaviour.

RECOMMENDATION:

That:-

1. **Subject to available funding, the current revision of the 2005 Tweed Valley Flood Study be expanded to include sensitivity modelling of climate change parameters (sea level rise and increased rainfall intensity) as recommended by the DECC Guideline and in accordance with the Floodplain Development Manual;**

2 **The results of this modelling be provided to the future consultant engaged to complete the Tweed Valley Floodplain Risk Management Study and Plan, and as a priority action instruct that consultant to undertake a review of flood planning levels adopted in the Tweed Valley Floodplain Risk Management Study Part 1 "Establish Appropriate Flood Planning Levels for Residential Development", in accordance with the DECC Guideline and the Floodplain Development Manual;**

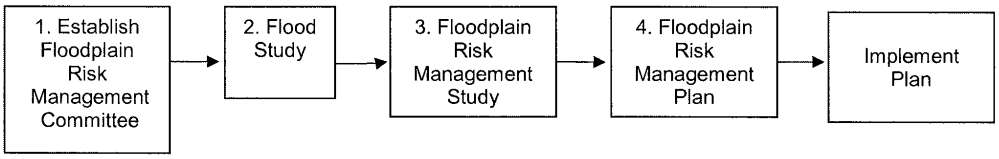
3. Climate change considerations be addressed in accordance with the DECC Guideline and the Floodplain Development Manual in the Coastal Creeks Flood Study, via minor variations to the issued technical brief.

REPORT:

Floodplain Risk Management Process

The NSW Government's adopted floodplain management system is contained in the 2005 "Floodplain Development Manual".

The floodplain management planning process can summarised as:-



Activity		Description
1	Establish Floodplain Risk Management Committee	Includes council, community and departmental representatives
2	Flood Study	Technical investigation of flood behaviour. Uses models to predict flood levels and velocities for a range of flood frequencies up to the PMF
3	Floodplain Risk Management Study	Hazard analysis. Identify and analyse management options including:- flood modification (mitigation), property modification, planning controls, flood planning levels, readiness/ response/recovery (SES), emergency response. In particular address cumulative impacts, larger floods (up to PMF),climate change.
4	Floodplain Risk Management Plan	Adopt preferred options from above study.
5	Plan Implementation	Enact planning controls (LEP, DCP etc), plan/finance/execute mitigation and property modification works, flood emergency plans, awareness programmes, ongoing data collection and monitoring

As detailed in previous reports to Council, a Floodplain Risk Management Process has been adopted and has commenced for the Tweed Valley and the Coastal Creek Floodplains, in accordance with the NSW Floodplain Development Manual (2005).

In the Tweed Valley, a Flood Study was completed in 2005, the first three parts of the Floodplain Risk Management Study have been completed (in house), and a consultant brief has been issued to complete the study and produce a Floodplain Risk Management Plan.

A revision of the 2005 Flood Study is currently being undertaken by BMT WBM, to integrate recently obtained airborne laser scanning (ALS) ground data into Council's flood model. This should provide increase accuracy in the prediction of design floods for the Tweed Valley.

The Coastal Creeks Flood Study has commenced and will take approximately 12 months to complete.

Government Advice on Climate Change

In line with the current widespread scientific acceptance of climate change, the State Government's Flood Prone Land Policy, and the 2005 Manual require Councils to recognise "the potential implications of climate change on flooding behaviour" when undertaking the Floodplain Risk Management Process.

With regard to flood studies, Appendix F6 of the Manual states the following:

> ***"F6 Climate Change***
> *A flood study should also address the possible implications of climate change on flooding behaviour… These include:*
> ❑ *increases in sea level. To date, a variety of scenarios exist for the likely increase in sea levels;*
> ❑ *altered weather patterns may intensify storms and so increase the severity of the resulting floods; and*
> ❑ *increased intensity and frequency of extreme events.*
>
> *The consequences of these increases on flood levels and behaviour should be analysed as part of a flood study either:*
> ❑ *qualitatively based upon the broad range of floods being examined (up to and including the PMF); or*
> ❑ *sensitivity analyses can be examined in relation to rainfall intensity, or downstream water level conditions for key flood events.*
>
> *This provides a preliminary assessment of the potential impacts of climate change on flooding so this can be considered in the management study…"*

A recent Floodplain Risk Management Guideline entitled "Practical Consideration of Climate Change" was issued by the Department of Environment and Climate Change (DECC) in October this year, which provides additional advice to assist in considering climate change in managing flood risk. The Guideline acknowledges that across the scientific community there is a range of potential impacts on sea levels and on flood producing rain due to climate change.

According to the United Nations' Intergovernmental Panel on Climate Change (IPCC) and the CSIRO, sea level rise on the NSW coast is expected to be in the range of 0.18 to 0.91m by between 2090 and 2100. The CSIRO has also predicted that for the Border Rivers, rainfall intensities for extreme rainfall events (the 1 in 40 year ARI, 1 day duration storm) are projected to increase by 3-7% by 2030 and 10-15% by 2070, and by as much as 29% in other regions.

The Guideline recommends that *"whatever climate change scenario is adopted (by Council, it) may be exceeded in the future as climate change continues. Therefore the precautionary principle suggests consideration of the full range of scenarios."*

The Guideline recommends that Council undertakes the following sensitivity analyses when undertaking flood studies:

For sea level rise:
— 0.18m (Low Level Ocean Impacts)
— 0.55m (Mid Range Ocean Impacts)
— 0.91m (High Level Ocean Impacts)

For increased rainfall intensity:
— 10% in peak rainfall and storm volume
— 20% in peak rainfall and storm volume
— 30% in peak rainfall and storm volume

Such modelling analyses are then used to inform the Floodplain Risk Management Study process, by identifying areas that are susceptible to increased flood risk due to climate change e.g. the formation of new floodways, reduced levee protection, increased frequency of inundation, loss of residential freeboard, increased flood damages.

Tweed Valley Flood Study Consideration of Climate Change

As the Tweed Valley Flood Study preceded the latest version of the Manual, climate change is not specifically addressed.

Section 4.3.3 of the Flood Study report details the adopted ocean level assumptions for each modelled design flood event. These levels were based on investigations by the Public Works Department in the 1980s on sea levels and storm surges. Draft DIPNR Floodplain Management Guideline No.5 - Ocean Boundary Conditions (2004) was also referenced as best practice in the selection of ocean levels at that time, and as such the adopted levels received concurrence from DIPNR officers.

It is considered that the Study's assumptions of sea level boundary conditions coming out of this process (that is a 1 in 100 year tide and surge level of RL 2.6m AHD) are conservative. This was highlighted in public submissions during exhibition of the Flood Study. A report prepared by Cardno Lawson Treloar on behalf of LEDA Design and Construction ("Cobaki Lakes Flood Assessment Ocean Water level Study", November 2004) recommended an ocean boundary condition of 2.1m AHD, with an additional allowance of 0.2m for mean sea level rise over 20 years. Similar levels were apparently used for flood studies in Ballina and the Gold Coast, although these authorities are likely to have added additional freeboard to account for climate change uncertainties.

Following liaison with DIPNR officers, it was agreed to retain the RL 2.6m AHD sea level assumption for the 100 year ARI design flood, as it provided an intrinsic allowance for future changes to sea level due to climate change for a reasonable planning timeframe.

Land & Environment Court Precedent

In a recent landmark decision, Justice Peter Biscoe overturned a decision by the Minister for Planning to approve the development of up to 285 homes and an aged-care facility at Sandon Point, north of Wollongong, under part 3A of the EP&A Act.

Justice Biscoe found the Minister had failed to consider "whether changed weather patterns would lead to an increased flood risk in connection with the proposed development in circumstances where flooding was identified as a major constraint on development of the site".

In his judgment, Justice Biscoe, referenced recent reports by the IPCC, and stated that "climate change flood risk is, prima facie, a risk that is potentially relevant to a flood-constrained coastal-plain development such as the subject project." He said it was in the public interest to factor global warming into a consideration of flood risk, but the Minister had failed to do so before approving a concept plan for redevelopment of Sandon Point.

According to this precedent, if Council is to utilise its flood studies and models as a basis for the determination of a development application, in order for such decisions to be legally defensible in light of this precedent, potential climate change impacts on flooding behaviour need to be specifically addressed by these studies.

Impact on Flood Planning Levels

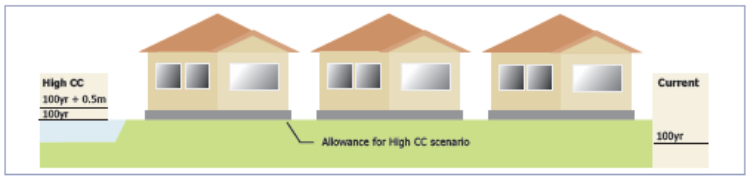
Part 1 of the Tweed Valley Floodplain Risk Management Study established flood planning levels (FPLs) for new residential development based on the results of the 2005 Flood Study. The 100 year ARI flood event was adopted as the design flood for the Tweed Valley, and residential freeboard was set at 0.5m.

The results of the sensitivity analyses recommended by the Guideline may necessitate review of these flood planning levels if sea level rise and/or increasing rainfall intensities significantly increase the frequency of inundation of urban land or reduces available freeboard to residential floor levels.

Various options for the review of FPLs are included in the Guideline, some of which are reproduced below. The appropriate time to review the FPLs is as part of the forthcoming Floodplain Risk Management Study consultancy.

Strategy Future 2 – Allow for High Scenario Climate Change Scenario Now

Minimum fill and floor levels include an allowance for high scenario climate change now. This allows for changes in rainfall intensities and sea level rise.

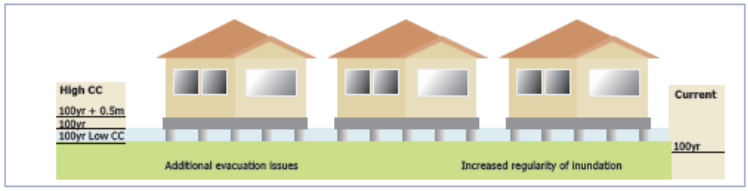


Strategy Future 3 – Development Conditions have No Climate Change Allowance

Minimum fill and floor levels based upon existing situation and additional flood risk due to climate change accepted.

Strategy Future 4 –High Level Climate Change Allowed for in Floor Levels. Low Climate Change in Fill Levels

Provides additional protection for homes with surrounding land inundated more regularly in the long term.

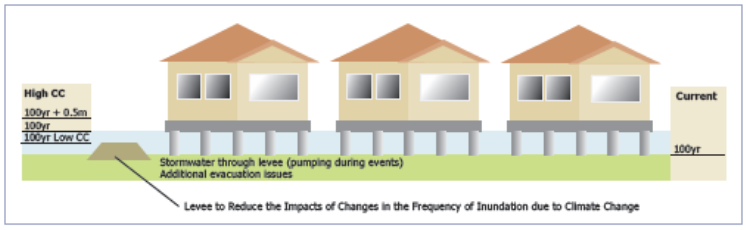


Strategy Future 5 – Fill to Current 100 year Flood Level. Floor Levels to High Climate Change Scenario

Provides protection to homes but will have increased frequency of inundation and therefore more emergency response issues. Depending upon frequency of inundation land may not be habitable in the long term.

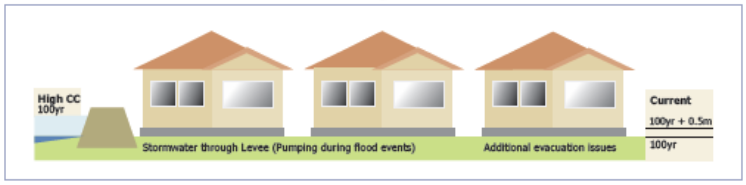
Strategy Future 6 – Minimum Fill Levels for Current 100 year. Floor Levels to High Climate Change. Levee to Reduce Frequecy of Inundation

Minimum Fill Levels for Current 100 year. Floor levels consider high climate change scenario. Levee built now or in the future to reduce frequency of inundation, possibly to low climate change scenario



Strategy Future 7 – Development Controls to Current Conditions. Levee Built to Manage Climate Change Impacts

Minimum fill and floor levels for current conditions. Levee built now or in the future to provide protection for climate change.



Local Floodplain Management & Planning Context

The proposed modelling of climate change parameters will enable both the Coastal Creeks Flood Study and "Tweed Valley Flood Study 2005" to be climate change compliant.

The soon to be commenced Tweed Valley Floodplain Risk Management Study can take this revised modelling into account when reviewing flood planning level and floodplain management options in the Tweed Valley. Consideration of climate change impacts on floodplain planning and management of the Tweed Valley could therefore commence in late 2008. Unfortunately the Coastal Creeks Flood Study will not be completed until late 2008 and it is likely to be well into 2009 before the subsequent Coastal Creeks Floodplain Risk Management Study will be commenced for this area. Consideration of climate change impacts on floodplain planning and management of the coastal creeks area is some years away.

Council has a number of locality and strategic planning studies currently underway. The NSW Department of Planning is also currently revising the land use and population densities proposed in the Tweed Heads Masterplan for both Tweed Heads and Tweed Heads South. Due to the above timetables, it is unlikely these studies will have the benefit of the climate change based modelling on flood behaviour.

Recommended Course of Action

It is recommended that, subject to available funding, the current revision of the 2005 Tweed Valley Flood Study be expanded to include sensitivity modelling of climate change parameters (sea level rise and increased rainfall intensity) as recommended by the DECC Guideline.

The results of this modelling should inform the Floodplain Risk Management Study for the Tweed Valley. As a priority, this information should be provided to the future consultant to conduct a review of flood planning levels adopted in Part 1 of the Tweed Valley Floodplain Risk Management Study.

Climate change considerations shall be adequately addressed in the Coastal Creeks Flood Study, with minor variations to the issued technical brief.

LEGAL/RESOURCE/FINANCIAL IMPLICATIONS:

Council's floodplain management process is currently funded via grant funding under the Natural Disaster Mitigation Program (NDMP) in a 1:1:1 Commonwealth : State : Council ratio. Approval to allocate grant funds for the climate change sensitivity analyses as part of the Tweed Valley Flood Study Revision and/or the Floodplain Risk Management Study consultancy is required from the NSW State Emergency Management Committee (SEMC) who administer the grants, based on quotations from the relevant consultants.

POLICY IMPLICATIONS:

The recommendations of this report will incorporate climate change parameters into the Tweed Valley and Coastal Creeks Flood Studies. The subsequent phase "The Floodplain Risk Management Study and Plan" will use the flood levels/frequency data from the Flood Studies to develop policies and actions on how to plan for and manage climate change induced flooding.

UNDER SEPARATE COVER/FURTHER INFORMATION:

*To view any **"non confidential"** attachments listed below, access the meetings link on Council's website www.tweed.nsw.gov.au or visit Council's offices at Tweed Heads or Murwillumbah (from Friday the week before the meeting) or Council's libraries (from Monday the week of the meeting).*

1. Floodplain Risk Management Guideline "Practical Consideration of Climate Change", Department of Environment and Climate Change, Version 1.0, 25 October 2007 (DW 1720684).